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INFORMATION SEARCH IN JUDGMENT TASKS: THE EFFECTS OF
UNEQUAL CUE VALIDITY..(U) ARIZONA UNIV TUCSON COLL OF
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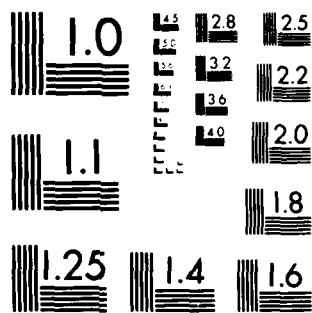
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ONR 84-1	2. GOVT ACCESSION NO. 11-1117	3. RECIPIENT'S CATALOG NUMBER 11-1117
4. TITLE (and Subtitle) Information Search in Judgment Tasks: The Effects of Unequal Cue Validity and Cost.		5. TYPE OF REPORT & PERIOD COVERED Interim Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Terry Connolly Patrice Serre		8. CONTRACT OR GRANT NUMBER(s) N00014-83-0742
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Arizona College of Business & Public Administration Tucson, Az 85721		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 170-965
11. CONTROLLING OFFICE NAME AND ADDRESS Organizational Effectiveness Research Programs Office of Naval Research, Code 4420E Arlington, VA 22217		12. REPORT DATE May 1984
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited. Reproduction in whole or in part is permitted for any purpose of the U. S. Government.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Approved for public release; distribution unlimited. Reproduction in whole or in part is permitted for any purpose of the U.S. Government		
18. SUPPLEMENTARY NOTES To appear in <u>Organizational Behavior and Human Performance</u> , 1985.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Information search; information purchase; judgment; decision making; cue validity; cue cost; deferred decision making; information cost; predecision processes.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This paper reports findings from three experiments on predecisional buying of information in experimental judgment tasks. In one study, cues were of equal validity and cost, but validity varied across conditions. In a second study subjects purchased from cues of equal validity but unequal cost, while in a third study the costs were of equal cost but unequal validity. The results support earlier findings that subjects find it difficult to balance costs and benefits of information acquisition. They commonly purchase less		

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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(in press)

INFORMATION SEARCH IN JUDGMENT TASKS:
THE EFFECTS OF UNEQUAL CUE VALIDITY AND COST

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Accession For

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Acknowledgements: We are grateful for helpful comments from Max Bazerman, Ed Conlon, Richard Harrison, Josh Klayman, Jay Russo, and two anonymous reviewers on earlier versions of this paper. Financial support was provided, in part, by Office of Naval Research Contract N 00014-83-K-0742 to the first author.

In a wide range of decision tasks the decision maker faces a choice as to how much to invest in acquiring decision-relevant information before making the final decision. Consumers invest in product-related information before purchasing (Jacoby, 1977), physicians in diagnostic tests (Elstein, Shulman and Sprafka, 1978), employers in selection tests (Guion, 1976), marketers in market surveys (Chestnut and Jacoby, 1982), and drilling companies in test wells (Raiffa, 1968). In each case, a complex balance must be struck between costs of acquiring information and the benefits of improved final decisions.

In an earlier paper (Connolly and Gilani, 1982) we reviewed the empirical literature on human performance in such information search tasks (see also the reviews of Peterson and Beach, 1967; Hershman and Levine, 1970; Rapoport and Wallsten, 1972; Slovic, Fischhoff and Lichtenstein, 1977; and Einhorn and Hogarth, 1981). The evidence suggests that:

1. Information acquisition is somewhat affected by normative considerations such as information quality and cost, but responses to variations in these factors are typically smaller than are normatively justified (e.g. Pitz, 1968; Wendt, 1969).
2. Normatively irrelevant factors, such as total information available, may also affect information acquisition (e.g. Levine, Samet, and Brahlek, 1975; Fried and Peterson, 1969).
3. Departures from optimal acquisition can be substantial, and appear in decisions with real monetary stakes as well as in play for inconsequential points or poker chips (e.g. Kleiter and Wimmer, 1974; Pitz and Barrett, 1969).
4. Learning of optimal acquisition strategies is slow or nonexistent in repeated play of laboratory games (e.g. Wallsten, 1968; Lanzetta and Kanareff, 1962).

5. Departures from optimal acquisition may be in the direction of over- or under-purchase (e.g. Hershman and Levine, 1970; Pitz, 1969).

6. There are substantial differences between individuals in their information acquisition (e.g. Pruitt, 1961; Levine et al., 1975. See also MacCrimmon and Taylor, 1976, for a detailed review).

Connolly and Gilani (1982) also noted that much of the experimental work to date has relied on Bayesian models, as in the familiar experimental procedure in which subjects purchase chips drawn from a bookbag before betting on the contents of the bag being sampled (Edwards, 1965). They proposed an alternative model for the regression (or continuous-variable) case, in which the decision maker purchases, over a series of trials, one or more cues, X_i , each of which is correlated with a true score, Y_e , which the decision maker attempts to estimate or predict. Prediction errors are penalized in proportion to the square of the difference between the subject's estimate, Y_s , and the true score, Y_e , on each trial. Specification of the cost, c_{ij} , and validity, $\rho_{x_i y_e}$, of each cue X_i , and of the constant d in the prediction-error penalty function $P_j = d(Y_e - Y_s)^2$ implies an optimal strategy for purchasing and using cues. In general, for given values of cue validity and cost, increasing the penalty for errors increases the number, N_{opt} , of cues that will minimize the subject's expected total cost (cue cost plus error penalty).

Connolly and Gilani reported the results of two experiments using a task based on this model. (The details of their procedure are given below.)

Limiting themselves to cue sets of equal cost and moderate validity ($\rho_{x_i y_e} = .85$), they found:

1. That subjects tended to overpurchase in tasks for which optimal pur-

chase was low ($N_{opt} = 1$), and to underpurchase in tasks for which optimal purchase was larger ($N_{opt} = 3$).

2. That subjects tended to purchase more heavily when eight cues were available than when offered a maximum of four cues.
3. That purchasing was heavier when the game was presented in a gain-maximizing, rather than a loss-minimizing, format, though the change of format had no effect in optimal strategy.
4. That subjects in three of the four experimental conditions improved their purchasing strategies with experience, though the improvement was modest, and departures from optimal purchasing were still substantial in late trials.
5. That, despite the statistical equivalence of the cue-sets offered, subjects formed strong beliefs as to the differential validity of the cues, and purchased in accordance with these (erroneous) beliefs.

In short, Connolly and Gilani's data support the earlier literature in suggesting that human skills in balancing the costs and benefits of information acquisition may be seriously deficient, even in a laboratory task in which the balance is made highly salient and extended opportunities for learning are provided. If these findings generalize to the range of real-world information-acquisition tasks noted earlier, they imply significant non-optimalities may be found in such tasks. The Connolly and Gilani findings were, however, restricted to tasks in which cues were of equal cost, and of equal and moderate validity.

A straightforward extension of Connolly and Gilani's model shows that, with other task parameters fixed, optimal purchase strategy, N_{opt} , is a single-peaked function of cue validity. Large purchases are normatively

justified, in general, only when cues are moderately valid. Low-validity cues do not yield enough reduction in decision error to justify their cost; and highly valid cues provide so much information that few are needed. An illustrative family of optimal purchase curves is shown in Figure 1 for a range of values of cue validity and cost. (Note that the curves are slightly displaced vertically for clarity.) The analogous relationship for the Bayesian model is developed by Edwards (1965). Snapper and Peterson (1971) found, in a task based on Edward's model, that subjects' actual purchasing behavior departed substantially from optimum. Subjects over-purchased when diagnosticity was low, under-purchased at intermediate levels of diagnosticity, and approximated optimal purchasing only for highly diagnostic information. It appears, then, that the nonlinear relationship between information quality and optimal purchase may not be intuitively obvious to naive subjects.

(Figure 1 about here)

The three experiments reported here extend Connolly and Gilani's findings to situations in which cue validity or cost varies. The first examines purchasing behavior over a range of cue validities, with cue cost and validity equal within each set. In the second experiment, cues offered were of equal validity but unequal cost. In the last experiment, cues were of equal cost but unequal validity. The broad intent was to extend the original findings to approximate more closely the situation of real-world information purchasers who, we assume, must generally select from cue sets differing in both validity and cost.

General Procedure

As in Connolly and Gilani (1982), subjects were instructed that they were to act as analysts for an imaginary company, Game Predictions Incorporated (GPI), that sold predictions of football game results to its clients. The predictions were based on the assessments of "football experts" on retainer to GPI. Each expert would, for a fee, provide an assessment of the likely pointspread on any game. Subjects were also told that GPI paid rebates to its clients when its predictions differed from actual game results. Fees paid to experts represented the information charge, c_{ij} , in the model, while client rebates represented the penalty charge, P_j .

In a change from the Connolly and Gilani (1982) procedure, the experiment was conducted in an interactive mode on a micro-computer. Instructions were presented on the screen with an opportunity for the subject to review any part. An experimenter was on hand to answer questions, and a hard-copy summary of the key points and the rebate chart was provided. The subject first read through the detailed task instructions explaining the activities of GPI, the task, and the pointspread metric used both for expressing expert assessments and for recording predicted and actual game results. Both screen and hard-copy instructions emphasized the goal of minimizing total cost by balancing expert fees and rebate costs. Finally, three sample displays of the format for expert predictions and game results were shown to familiarize the subject with the screen layout.

For each of the experimental conditions described below, subjects first played, for practice, 30 games described as having been drawn from results the previous season. For these games, all experts provide assessments free of charge. After all assessments appeared, the subject was asked to enter a prediction of how the game would turn out. (S)he was then shown the actual

game result, the prediction error (if any), and the penalty (rebate charge) that would have been charged. These practice games were intended to allow the subject to become familiar with the experimental procedure, and to assess the value of each expert in relationship to actual game results and rebate charges.

The second phase of the experiment involved prediction of 30 "real" games, for which expert fees and rebate charges were recorded. For each game, the subject first entered the total number of experts (s)he wished to purchase on that game, and the identifying numbers of those experts. Any assessments bought were displayed on the screen. The subject then entered a prediction of the game result. The actual game result was then shown, the error and rebate charge computed, and a summary of information cost and rebate, both for that game and a running total for all games played, were then displayed. After completing these 30 games, the subject completed a brief post-experimental questionnaire presented on the screen, and was then debriefed and released by the experimenter.

The subjects were engineering students at Georgia Institute of Technology, satisfying a course requirement by laboratory participation. They were run individually, with each experimental session lasting approximately 45 minutes.

Task Parameters

Actual game results Y_e were drawn from a Normal (0,225) distribution, so that about 2/3 of all games were decided by pointspreads of 15 points or less. Expert assessments were generated by adding to Y_e an error term normally distributed with zero mean and variance selected to yield the desired

cue validity (see below), with the sum scaled so as to equate variance of assessments and true scores.

Experiment 1

The first experiment had two primary purposes: to examine the comparability of information-purchase behavior between the present computer-interactive format and the manual procedure used by Connolly and Gilani; and to explore the generalizability of their results across a range of values of cue validity. Three cue-validity conditions were selected: .75, .85 and .95. Correlations smaller than about .70 are not readily detected by subjects when the pairs of numbers are presented sequentially (Jennings, Amabile and Ross, 1982). Correlations of .95 are readily detected. The intermediate value of .85 replicates the value used in the earlier studies.

In this experiment, cue validity was fully crossed with a second factor, N_{opt} , the optimal number of cues to purchase on each trial. Cue cost, c_{ij} , was kept constant at \$10 per game, and the penalty cost constant, d , was set to produce optimal purchase conditions of one, two or three cues per game. Each subject participated in only one condition of cue validity and N_{opt} . Six subjects were randomly assigned into each of the nine conditions, for a total of 54 subjects.

Results

The overall pattern of cue purchasing is shown in Figure 2. As in Connolly and Gilani (1982), subjects tended to overpurchase in the $N_{opt}=1$ conditions, and to underpurchase in the $N_{opt}=3$ conditions. More cues were purchased in the moderate validity condition than in the high validity condition for all three values of N_{opt} , though this pattern of increasing purchase with declining validity does not extend to the lowest validity

conditions

(Figure 2 about here)

To examine the possibility of learning over the 30 experimental games, purchasing behavior was computed separately for the first and last 15 trials in each condition, allowing a $3 \times 3 \times 2$ (Repeated Measure) ANOVA. This analysis shows a significant effect both for validity condition ($F = 5.01$; $p < .01$) and optimality condition ($F = 13.82$; $p < .001$), with no significant interaction ($F = 1.81$; ns). Neither validity nor optimality showed a significant main effect on learning, though there was a significant interaction effect ($F = 3.14$; $p < .03$). Purchasing was closer to optimal in later trials for all three high-validity conditions, and for the $N_{opt}=3$ conditions of the moderate and low-validity groups.

The post-experimental questionnaire asked the subjects to rate the accuracy of each expert on a five-point scale anchored at 1 ("Very inaccurate") and 5 ("Very accurate"). The four cues offered each subject were, within sampling variability, of equal validity. They were, however, seen by the subjects as of widely different accuracy: the mean difference between highest and lowest ratings was 2.1 in the .75 validity condition, 2.0 in the .85 validity condition, and 2.1 in the .95 validity condition. These ratings were also strongly associated with actual purchasing behavior. The correlations of ratings and frequency of buying of each expert showed a mean of .58 for the low-validity cues, .38 for the moderate-validity cues, and .48 for the high-validity cues (all significantly different from zero; $p <$

.01). Mean ratings were not significantly different across validity conditions ($F = .45$; ns).

Overall these findings confirm and extend those reported by Connolly and Gilani (1982). The results reported here for the .85 validity and condition are strikingly similar to those in the earlier study, suggesting that they are robust to the shift from the earlier manual procedure to the present computer-interactive format. The pattern of overpurchase for $N_{opt}=1$ tasks, and underpurchase for $N_{opt}=3$ tasks appears robust across variations in cue validity from highly valid cues (.95) to levels at which subjects may have had difficulty in detecting any reliable relationship between cue and true score (.75). When cues are highly valid, fewer were purchased overall, and modest learning was seen in comparing the first and last half of the experimental trials. There is no clear pattern relating purchase of the least valid cues to optimality condition.

Experiment 2

In this experiment, subjects were offered four equally valid cues, of validity .75, .85, or .95, depending on experimental condition. Two cues were priced at \$10 per game, the other two at \$20 per game. Within each validity condition, half the subjects were offered Experts 1 and 3 at \$20 each, the other half were offered Experts 2 and 4 at this price. The game was otherwise identical to that used in Experiment 1, with penalty function set so as to make a purchase of one \$10 cue per game optimal. Six subjects participated in each cue-validity condition, for a total of 18 subjects.

Results

Overall cue purchasing behavior is shown in Figure 3. As in Experiment 1, $N_{opt}=1$, subjects generally overpurchased, though less when the cues were highly valid than when validity was low. (The effect of cue validity is here not statistically significant: $F = 2.73$; $p < .11$). The most striking finding here, however, is the extent to which the more expensive (though no more valid) cues were purchased. In the low cue-validity condition, 29% of all cues purchased were at the \$20 price; in the moderate-validity condition, 21%; and in the high-validity condition, 39% (no significant difference across validity conditions). Overall, 29% of all cues purchased were those bearing the higher price.

(Figure 3 about here)

As in the earlier experiments, these subjects report sizable differences in perceived accuracy of the experts they were offered. Only two of the 18 subjects rated all four experts as equally accurate on the post-experimental questionnaire scales. The mean difference between highest and lowest rating was 2.2 scale points. However, unlike the previous studies, these ratings were not significantly associated with buying behavior; the correlation of rating and frequency of buying each expert was .10 in the low-validity condition, .15 in the moderate-validity condition, and .22 in the high-validity condition. Mean ratings showed no significant difference across validity conditions (means 2.6, 2.2, and 2.6; n.s.), nor across cue-cost (mean rating for \$10 cues: 2.4; for \$20 cues, 2.5; n.s.). It appears, then, that the combination of unequal cost and equal validity of cues left the subjects somewhat confused. They report sizable differences in cue

validity, but these assessments appear unrelated to actual buying behavior. The most striking finding, however, is that, offered a choice between equally valid cues, some of which cost twice as much as the others, some one in three of all purchases were of the more expensive cues.

Experiment 3

In this experiment subjects were offered four equally costly cues (at \$10 each per game) of unequal validity. In one condition, two of the cues were of high validity (.95), two were of low validity (.75). In a second condition, two cues were of high validity, two of moderate validity (.85) and in the third condition, two were of moderate, two of low, validity. Within each condition, half the subjects were offered the more valid cues as Experts 1 and 3, while the other half were offered these cues as Experts 2 and 4. The game was otherwise identical to that used in Experiment 1, with penalty function set so as to make the purchase of one of the more valid cues per game optimal. Six subjects participated in each condition, for a total of 18 subjects.

Results

Overall cue purchasing behavior is shown in Figure 4. Again paralleling the $N_{opt}=1$ condition of Experiment 1, subjects generally overpurchased in all three validity conditions, with no significant difference in total purchasing across cue-validity conditions. The most striking result, however, is the extent to which subjects purchased the less valid cues they were offered. Overall, some 28% of all cues purchased were from the less valid pair in each mixture. Purchasing appears somewhat closer to optimal in condition 1 (cues of .95 and .75 validity), where only 11.4% of purchases

were of the less valid cue, than in conditions 2 and 3, where the less valid cues accounted for 35.7% and 37.6% respectively of all purchases. The difference across validity conditions fails to reach statistical significance, however ($F = 1.74$; ns).

(Figure 4 about here.)

As in earlier experiments, subjects perceived substantial differences in the validity of the cues offered. On the post-experimental questionnaire, only two subjects rated the four experts equally accurate, and the mean difference between highest and lowest accuracy rating was 2.1 (on the 5-point scale). These ratings reflect, to some extent, the actual differences in cue validity. In condition 1 (validity .95 and .75), the mean rating for the more valid cues was 3.5, against 1.9 for the less valid cues ($t = 5.27$; $p < .002$). In condition 2 (validity .95 and .85), the respective mean ratings were 3.2 and 2.6 ($t = 1.34$; ns), and in condition 3 (validity .85 and .75), the mean ratings were 3.6 and 2.7 ($t = 1.54$; $p < .10$). These assessments are also strongly related to actual buying behavior. The correlation between accuracy ratings and actual purchase frequency is .77 for condition 1, .64 for condition 2, and .81 for condition 3 (all significantly different from zero: $p < .001$).

There is evidence, then, that subjects offered cues of differential validity were able to detect the difference, and to shape their buying strategies accordingly. This insight into the task conditions, however, was insufficient to produce a close approximation to optimal strategy: some one of every three cues purchased was less valid than another cue offered at the same time; and, as in other $N_{opt}=1$ conditions, the overall pattern was of

substantial overpurchase.

Discussion

The broad question addressed by this research is: How good are humans at balancing the costs and benefits of their information acquisition? Do they buy those, and only those, sources of information whose acquisition cost is outweighed by the improvement in decision quality that their use makes possible? The evidence reported here, together with that reviewed earlier, suggests that the answer is not encouraging. Specifically, the present findings extend those noted earlier in suggesting:

1. That the pattern of overpurchase for low-consequence decisions, and underpurchase for high-consequence decisions, is robust to variation in overall cue validity, as well as to procedural modifications such as manual versus computer-interactive transactions (Experiment 1).
2. That overpurchase is frequently coupled with mispurchase (Experiments 2 and 3). That is, subjects, in addition to buying overall more information than was normatively justified, frequently bought expensive cues when cheap, equally-valid ones were available (Experiment 2), or low-validity cues when higher-validity, equally-costly cues were available (Experiment 3).
3. That subjects perceive equally-valid cues as of differential validity (Experiments 1 and 2), and are able to detect real validity differences between cues reliably only when the differences are large (Experiment 3). Purchase behavior is generally shaped by these perceptions of validity, whether well-founded or not, though the relationship disappears when equally-valid cues are offered at different costs (Experiment 2).
4. That, although modest learning was seen in some cases, these departures from optimality persisted to the end of the experimental period.

It does not appear that these results are adequately accounted for merely as manifestations of the "flat maximum" problem (von Winterfeldt and Edwards, 1982). Several investigators (e.g. Wendt, 1969; Rapoport and Wallsten, 1972: 169) have noted that information-search models tend to have total cost curves with rather flat maxima, in the sense that moderate deviations from optimal purchase do not greatly increase costs in the general case. The present model shares this characteristic (see Connolly and Gilani, 1982: 335-336). However, the parameter values chosen for the present experiments often led to substantial penalties for purchase errors. Table 1, for example, shows the percentage increase in expected total cost resulting from over- or under-purchasing by one cue in Experiment 1 (assuming optimal use of information purchased).

(Table 1 about here)

Mispurchase in cells where cues are highly valid and optimal purchase small is sharply penalized. Similarly, in Experiment 2, subjects buying a single \$20 cue instead of the \$10 cue could expect to increase their total costs by 45.1% in the .75 validity condition, by 60.2% in the .85 validity condition, and by 83.0% in the .95 validity condition. In Experiment 3, purchase of the less valid cue of those offered increased expected total costs by 33.3% in the ML condition, by 37.8% in the HM condition, and by 83.8% in the HL condition. (These figures underestimate actual penalty, since the subjects in Experiments 2 and 3 bought too many, as well as wrongly selected, cues). In short, at least some of the non-optimal purchasing observed in these experiments persisted in the face of substantial cost penalties.

A second possibility is that the subjects were responding to some loss function other than the squared-error function used in deriving

optimal strategies (c.f. Peterson and Miller, 1964; Brehmer and Kuylenstierna, 1978). They might, for example, be responding to error, rather than penalty, despite the efforts made in the experimental instructions to stress the shape of the penalty function both graphically (on the screen and with a paper copy provided) and verbally (emphasizing that large losses were penalized proportionally more than small ones). It is, of course, possible that the subjects maintained some variant loss function despite these efforts. However, unless such variants were related to experimental condition, it is difficult to see how they can account for both under- and over-purchase. For example, minimizing error (rather than squared error) would have led subjects toward consistent underpurchase by the standards of the model. Variant loss functions, then, while certainly possible, do not provide any obvious and parsimonious explanation of the data.

This is, evidently, a difficult task for the subjects to master within a 30-trial learning period: final levels of performance are substantially short of optimal, and modest learning may continue throughout the experimental period. Part of the difficulty may stem from failure to make correct assessments of the validities of the several cues presented. This latter component of the task is made more difficult by the intercorrelation between the cues. A subject who has reduced his or her error by some amount by purchasing one cue will achieve a smaller reduction by buying a second cue of the same validity, a third cue will contribute still less, and so on. The subject may rate these later cues as less "valid" than the first, recalling that they were less useful, on the average, in reducing error. Though cues were, in this experiment, purchased en masse rather than sequentially within each trial, the subjects may well have attended to them in some sequential way, making difficult the assessment of their validity

and thus, in turn, the development of an optimal strategy.

Extrapolation from these findings to the real-world contexts noted earlier is, as always, problematic. On the one hand, student subjects working for a relatively brief period on an unfamiliar task in which they have no substantial stake clearly do not reflect many of the features of their real-world counterparts. On the other hand, the experimental procedures attempted to make as salient as possible the required balancing of information cost and benefit; information charges and error penalties were commensurable and updated each game; immediate feedback was provided over a long run of trials; adequate opportunity was provided to sample and assess each of the cues in the practice period before the experimental trials; and the cognitive work required to utilize the information acquired was minimized. In short, while the findings are clearly subject to the usual laboratory restrictions, we believe that they provide at least a basis for developing hypotheses as to real world information acquisition behaviors.

The general hypothesis suggested by this and earlier studies is that real-world information gathering may be seriously suboptimal. The laboratory evidence provides little basis for optimism that individuals will routinely be able to select the most cost-effective mix of informational inputs on which to base their decisions. Elstein (1976), for example, reports extensive purchasing by physicians of diagnostic tests of dubious value (through the cost effectiveness issue is here confounded by third-party payment effects). The widespread practice of interviewing job applicants, despite the expense and poor predictive validity of the information so gathered (see Guion, 1976), might similarly represent a wasteful use of information gathering resources.

The issue is particularly pressing to the designers of management information systems and similar computer-based systems intended to support

judgmental decisions such as those considered here. The designer of such a system would be ill advised to place a great credence either on the decision maker's assessments as to which information sources are of value, or on his or her existing patterns of information use. On the present evidence, it appears that information users are likely to be poor sources of such design guidance (see also Ackoff, 1967). Instead, the designer who must decide which sources of costly information to provide to the decision maker must make an independent assessment of the costs and decision relevance of possible sources, drawing on whatever actuarial information is available to guide the choice. The decision maker's preference or practice in such matters seems unlikely to provide adequate guidance.

The overall thrust of the present study, together with that of Connolly and Gilani (1982), is to reinforce and extend the earlier evidence based on *Bayesian models for serious departures from optimality in information purchasing*. There appears to be a consistent bias towards moderate information purchasing, with the result that too little is acquired when decision stakes are large, and too much when decision stakes are low. This pattern appears robust across a moderate range of cue validities. Information users do not appear as reliable judges of differential validity within a cue set, nor do they consistently buy from the cheapest of available, equally-valid sources. The size of these departures from optimality in the simplified laboratory context suggests that large and costly departures may frequently be found in comparable real-world settings.

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Table 1: Percentage Increase in Expected Total Cost
Resulting From Purchase Errors of ± 1 Cue,
Experiment 1.

n_{opt}	$\rho_{iy} = .95$	$\rho_{iy} = .85$	$\rho_{iy} = .75$
1	74.9%	43.5%	25.4%
2	13.1%	10.6%	8.2%
3	5.6%	4.8%	3.9%

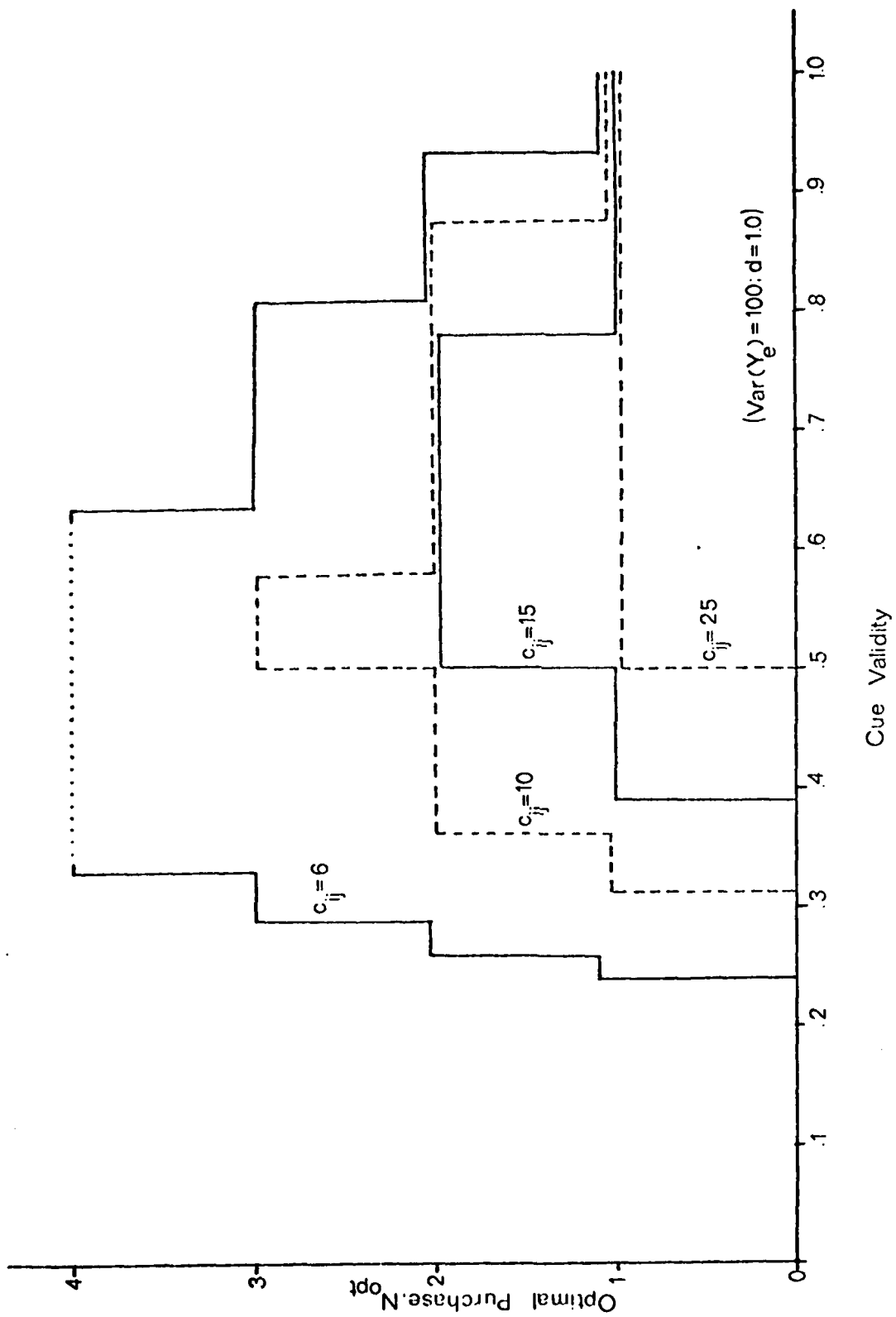


Figure 1: Optimal Information Purchase versus Cue Validity

for various values of Cue Cost, c_{ij}

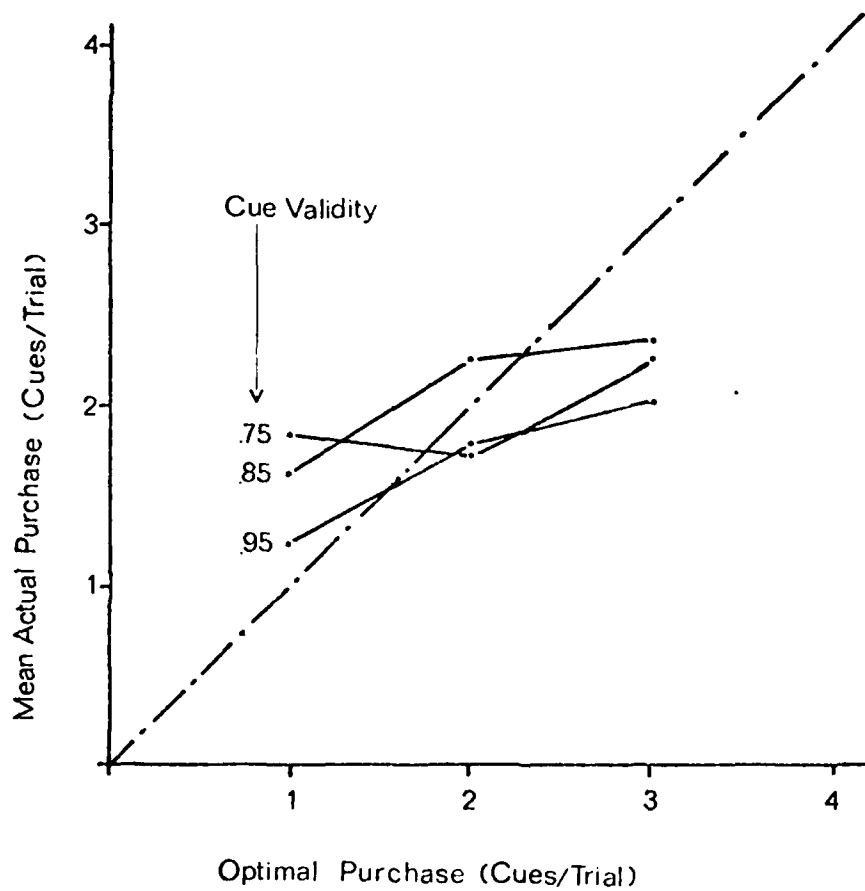


Figure 2: Actual vs. Optimal Information Purchase, Experiment 1

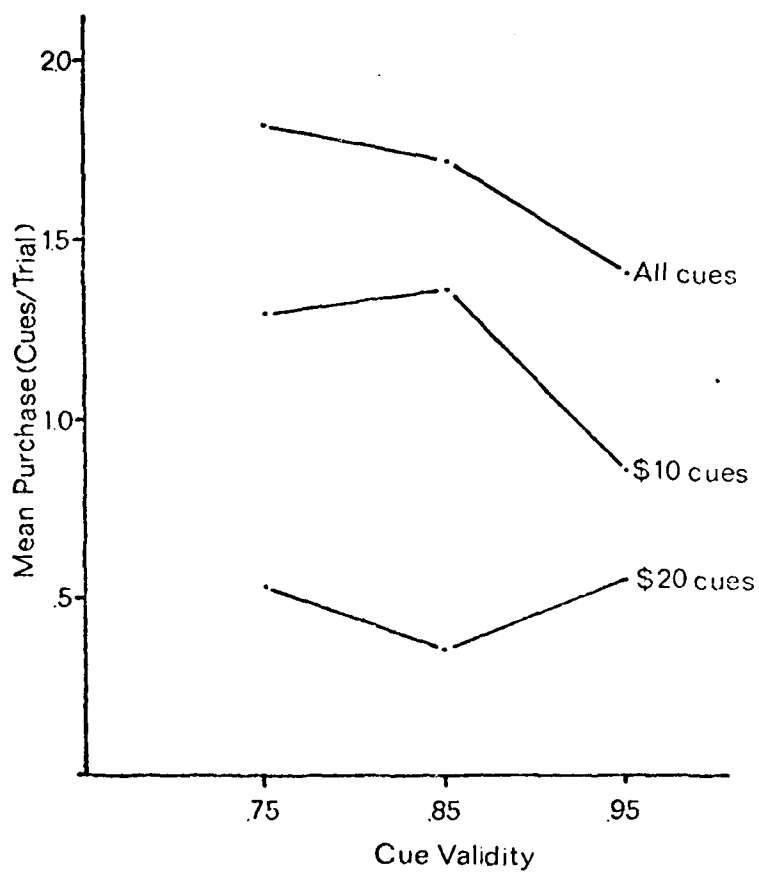


Figure 3: Mean Cue Purchase vs. Cue Validity, Experiment 2

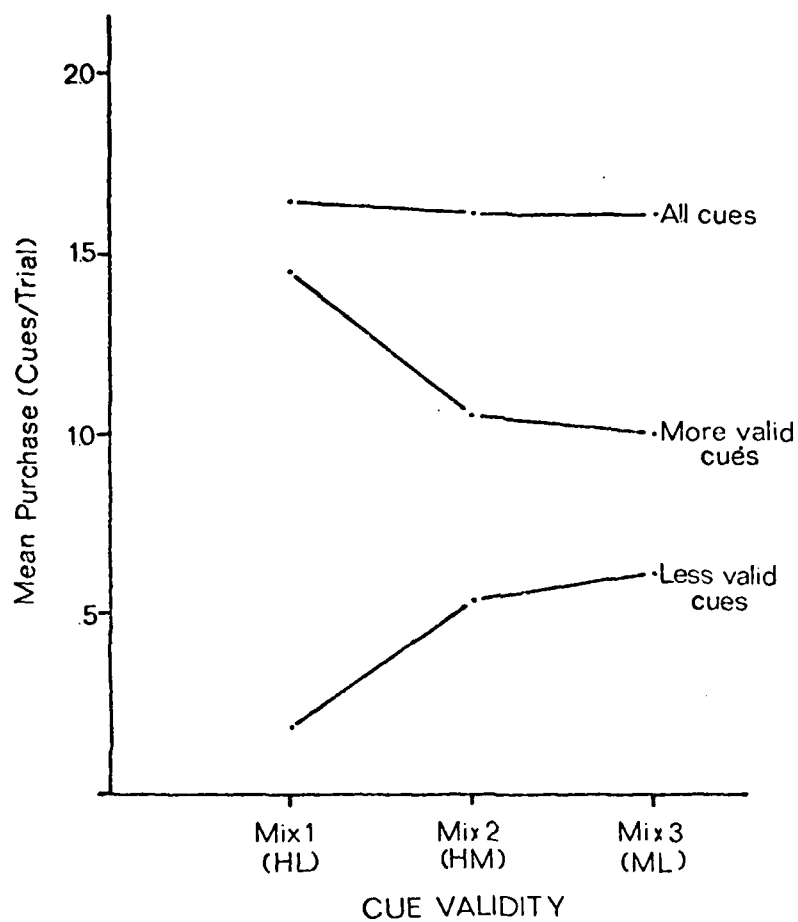


Figure 4: Mean Cue Purchase vs. Cue Validity Mix, Experiment 3

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